Photosynthesis and Atmospheric Change Laboratory

BROOKHAVEN NATIONAL LABORATORY

Leaf Photosynthesis and Carbohydrate Levels of Perennial Ryegrass Exposed to Elevated [CO_2] and Two N Fertilization Treatments

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Background

- Previous research has shown that acclimation of photosynthesis to elevated [CO_2] is present under low N conditions in *Lolium perenne*, whereas under high N conditions, acclimation is absent (Rogers *et al.* 1998). Is this trend consistent after 8 years of sustained exposure to elevated [CO_2]?

- Loss of photosynthetic capacity with growth at elevated [CO_2] is commonly linked to an inability of the plant to use additional photosynthate (Drake *et al.* 1997, figure 1). Is this observed in *L. perenne* exposed to elevated [CO_2]?

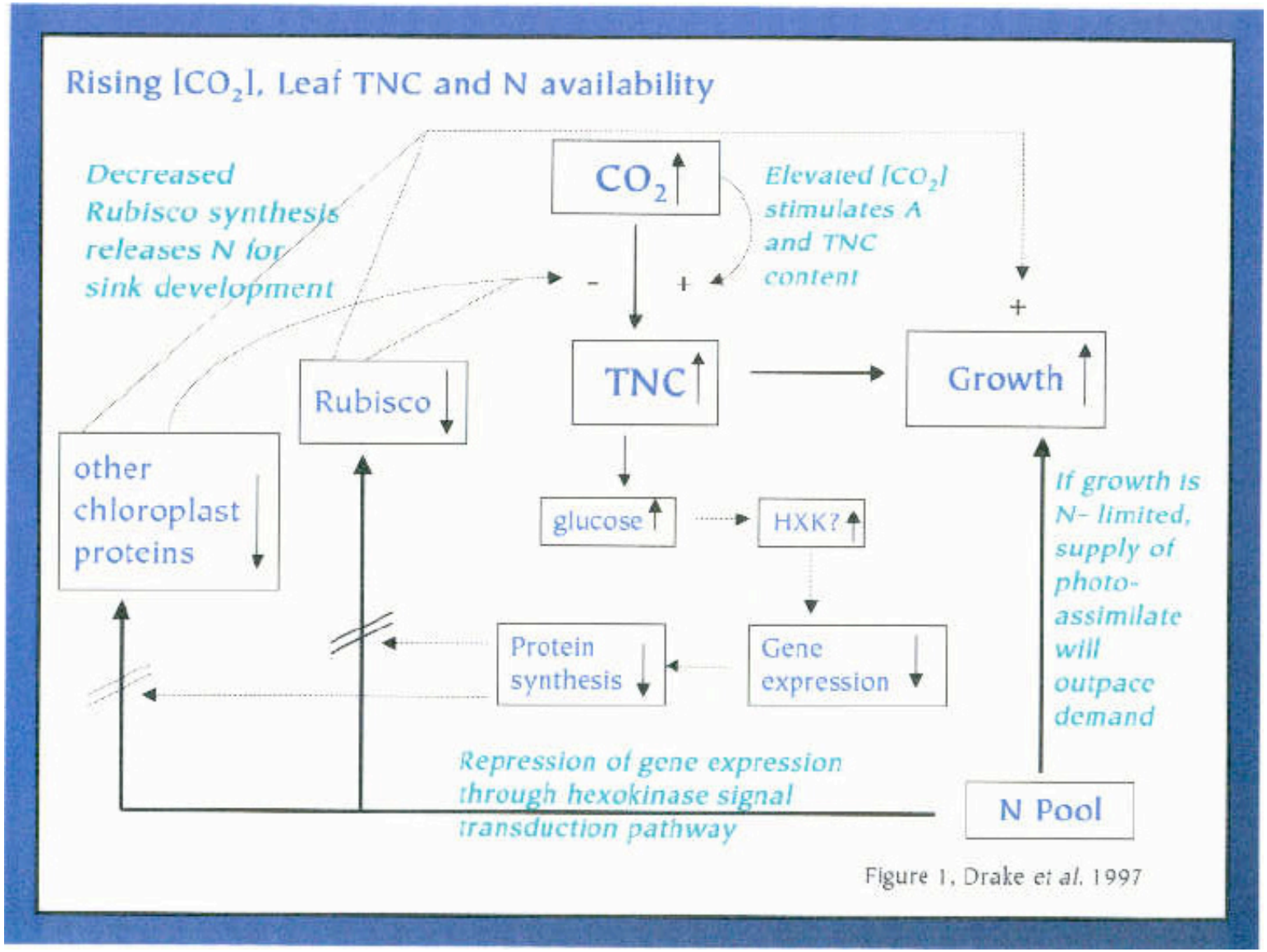


Figure 1, Drake *et al.* 1997

Experimental Site

- *Lolium perenne* L. has been exposed to elevated [CO_2] for the past 8 years in the Swiss FACE experiment.

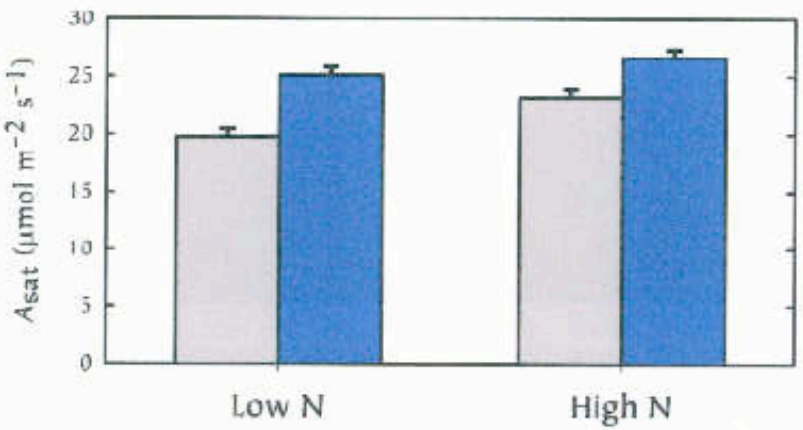
- The Swiss FACE facility contains 3 pairs of control and fumigated plots, maintained at current and 600 ppm [CO_2].

- N fertilizer is added to monoculture stands of *L. perenne* in two treatments, Low N (140 g m^{-2} yr^{-1}) and High N (560 g m^{-2} yr^{-1}).

Methods

- Leaf photosynthetic CO_2 uptake rate (A) was determined in response to changes in the intercellular [CO_2] (c_i) for *L. perenne* in April 2001.
- *L. perenne* leaves for carbohydrate analysis were sampled midday on 30 Apr 2001, frozen in liquid N and kept at −80°C.
- Photosynthetic parameters were calculated by fitting the equations of Farquhar *et al.* (1980) following the methods of McMurtrie and Wang (1993).
- *In situ* diurnal photosynthetic measurements of *L. perenne* were taken at two hour intervals on 28 Apr 2001. Leaves were sampled for carbohydrate analysis at dawn and dusk on 28 Apr and at dawn on 29 April.
- Carbohydrate levels in the leaves were analyzed using a phenol-sulfuric acid assay (Rogers *et al.* 1998).

Results - Photosynthesis



Asat Statistics

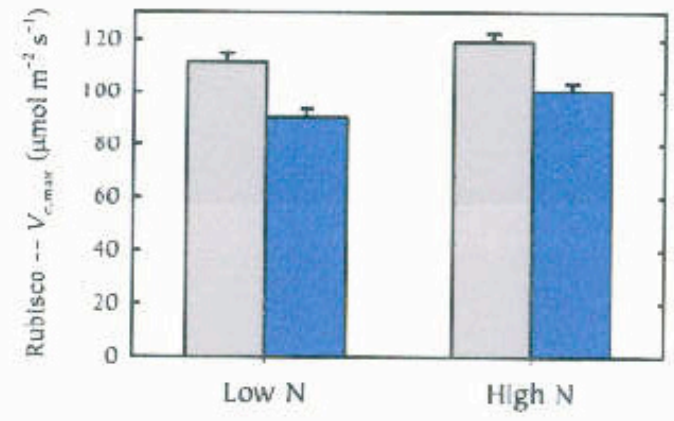
CO_2	$p < 0.05$
N	ns
CO_2 X N	ns

Control
Fumigated

- Growth in elevated [CO_2] stimulated light-saturated photosynthesis by 20%.
- Nitrogen did not significantly affect A_{sat}.

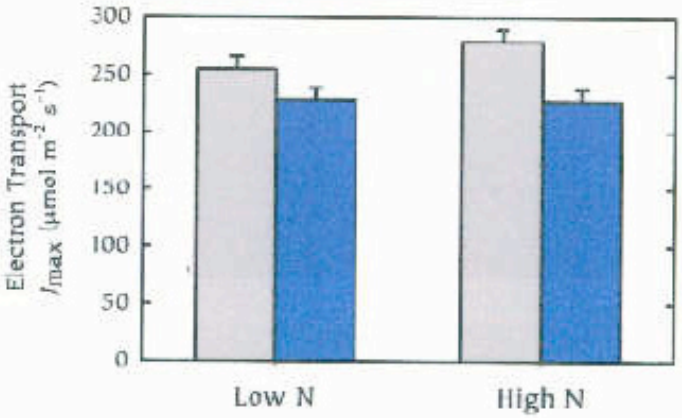
- Growth in elevated [CO_2] resulted in 21% decrease in the rate of Rubisco carboxylation ($V_{c,max}$) and 18% decrease in maximum electron transport contributing to RuBP regeneration (J_{max}).

- Down regulation of photosynthesis to elevated [CO_2] occurred in both low N and high N treatments.



Vc,max Statistics

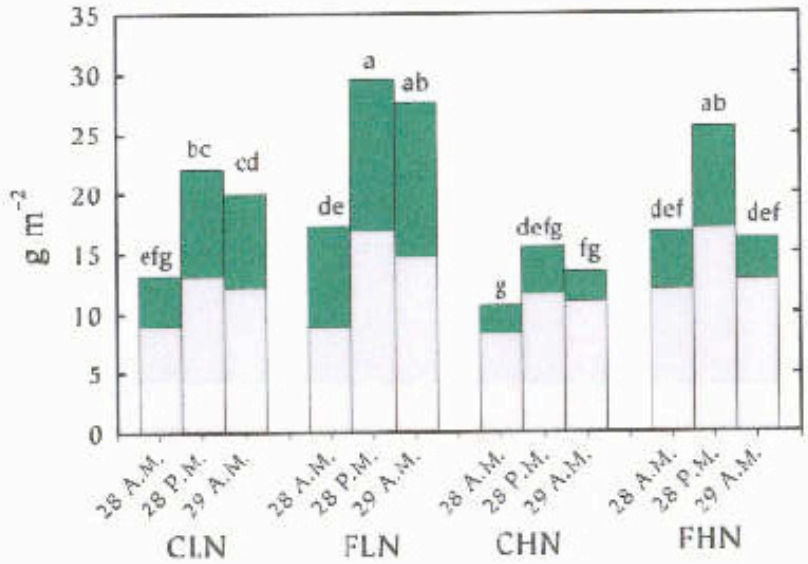
CO_2	$p < 0.05$
N	$p < 0.05$
CO_2 X N	ns



Jmax Statistics

CO_2	$p < 0.05$
N	ns
CO_2 X N	ns

Diurnal Carbohydrate Fluxes



TNC Statistics

CO_2	$p < 0.1$
N	$p < 0.05$
CO_2 X N	ns
Time	$p < 0.0001$
Time X CO_2 X N	ns

- Leaves were sampled for carbohydrate analysis on 28 Apr at dawn (28 A.M.) and dusk (28 P.M.) and again the next morning on 29 Apr at dawn (29 A.M.).

- Pre-planned comparisons of paired differences in class means were separated. Different letters represent significantly different class means at alpha = 0.05, for each comparison.

Diurnal Photosynthesis and Carbohydrate Fluxes

- Diurnal carbon fixation estimated from leaf gas exchange measurements on 28 Apr 2001 were not affected by [CO_2] or N treatments.
- Plants grown under Low N conditions had a net TNC accumulation from 28 Apr a.m. to 29 Apr a.m.
- Plants grown under High N conditions had no net TNC accumulation.

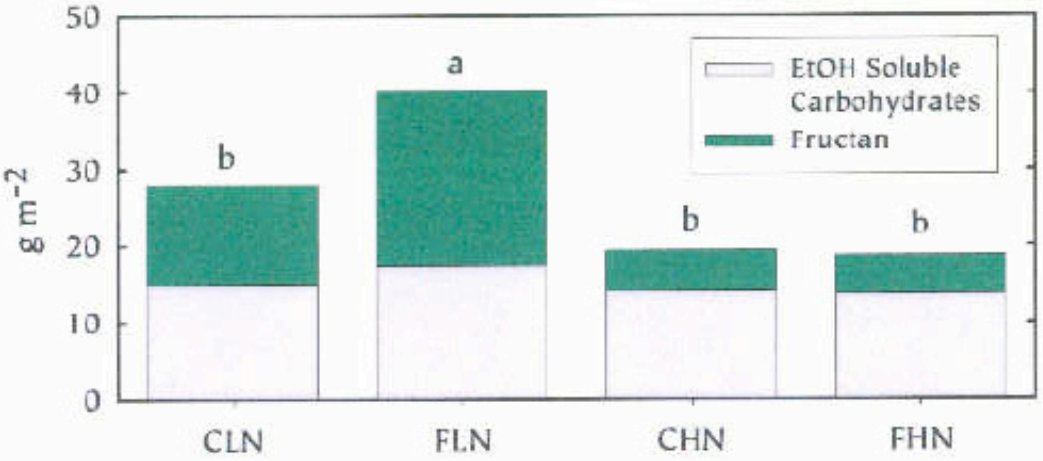
28 Apr 2001 Carbon Fixation

Plot	g C / photoperiod
CLN	8.5 ± 0.6
FLN	8.8 ± 0.5
CHN	8.6 ± 1.2
FHN	10.1 ± 0.7

TNC accumulation (28 Apr a.m. to 29 Apr a.m.)

Plot	g Carbon
CLN	6.7 ± 1.1
FLN	9.1 ± 2.0
CHN	1.0 ± 2.3
FHN	-0.5 ± 4.3

Midday Total Nonstructural Carbohydrate Levels – 30 Apr 2001



TNC Statistics

CO_2	ns
N	$P < 0.05$
CO_2 X N	$p < 0.1$

CLN: Control CO_2, Low N

FLN: Fumigated, Low N

CHN: Control CO_2, High N

FHN: Fumigated, High N

- *L. perenne* grown under low N conditions had significantly higher levels total nonstructural carbohydrates (TNC = EtOH soluble + Fructan) ($p < 0.05$) due to higher levels of fructan ($p < 0.05$).
- Ethanol soluble carbohydrate (glucose, fructose, sucrose) levels were not affected by growth [CO_2] or N treatment.

Conclusions and Further Questions

- Long-term exposure of *Lolium perenne* to elevated [CO_2] has resulted in significant acclimation of photosynthesis, in both Low N and High N fertilization treatments. Is leaf N content reduced in elevated [CO_2]?
- Analysis of midday leaf carbohydrate levels revealed that plants grown in Low N at elevated [CO_2] had elevated levels of TNC. Are Rubisco protein and RNA levels reduced in these leaves?
- Plants grown under Low N conditions appear to be sink-limited, accumulating TNC in leaves from 28 Apr a.m. to 29 Apr a.m. Will evidence of sink limitation disappear after a cut?

References

Drake BG, Gonzalez-Meler MA, Long SP (1997) *Annual Review of Plant Physiology and Plant Molecular Biology* 48: 609-639.

Farquhar GD, Von Caemmerer S, Berry JA (1980) *Planta* 149: 78-90.

McMurtrie RE, Wang YP (1993) *Plant Cell & Environment* 16: 1-13.

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Acknowledgments

- Swiss Federal Institute of Technology (*ETH*)
- University of Illinois, Graduate Travel Grant
- Global Change Education Program
- Brookhaven National Laboratory